KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

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Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603

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Origin of big garnets in amphibolites during high-grade metamorphism, Adirondacks, NY
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Students: Denny Alden, Erica Emerson, Kathryn Stack

Carbonate Depositional Systems of St. Croix, US Virgin Islands
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Students: Monica Arienzo, Ashley Burkett, Alexander Burpee, Sarah Chamlee, Timmons Erickson
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Sedimentary Environments and Paleoecology of Proterozoic and Cambrian "Avalonian" Strata in the United States
Mark McMenamin (Mount Holyoke College) and Jack Beuthin (U of Pittsburgh, Johnstown)
Students: Evan Anderson, Anna Lavarreda, Ken O'Donnell, Walter Persons, Jessica Williams

Development and Analysis of Millennial-Scale Tree Ring Records from
Glacier Bay National Park and Preserve, Alaska (Glacier Bay)
Greg Wiles (The College of Wooster)
Students: Erica Erlanger, Alex Trutko, Adam Plourde

The Biogeochemistry and Environmental History of Bioluminescent Bays, Vieques, Puerto Rico
Tim Ku (Wesleyan University) Suzanne O'Connell (Wesleyan University), Anna Martini (Amherst College)
Students: Erin Algeo, Jennifer Bourdeau, Justin Clark, Margaret Selzer, Ulyanna Sorokopoud, Sarah Tracy

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Keck Geology Consortium: Projects 2007-2008
Short Contributions – Alaska

DEVELOPMENT AND ANALYSIS OF TREE RING RECORDS FROM GLACIER BAY NATIONAL PARK AND PRESERVE, ALASKA: p238-243

Project Faculty:
GREG WILES: The College of Wooster
DANIEL LAWSON : Cold Regions Research and Engineering Laboratory

RECONSTRUCTION OF SITKA, ALASKA TEMPERATURES (1569-1991) BASED ON EIGHT GULF OF ALASKA TREE-RING CHRONOLOGIES: p244-249

ERICA ERLANGER: Union College
Research Advisor: Jaclyn Cockburn

ASSESSING THE PACIFIC NORTH AMERICAN TELECONNECTION: LAURENTIAN GREAT LAKES WATER LEVELS AND GULF OF ALASKA TREE GROWTH: p250-255

ADAM J. PLOURDE: Colorado College
Research Advisor: Eric M. Leonard

DENDROCLIMATOLOGY AND DIVERGENCE: A CASE STUDY FROM GLACIER BAY NATIONAL PARK AND PRESERVE, ALASKA: p256-260

ALEXANDER A. TRUTKO: The College of Wooster
Research Advisor: Johannes Koch

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Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
Keckgeology.org

DEVELOPMENT AND ANALYSIS OF TREE RING RECORDS FROM GLACIER BAY NATIONAL PARK AND PRESERVE, ALASKA

GREG WILES: The College of Wooster
DANIEL LAWSON : Cold Regions Research and Engineering Laboratory

BACKGROUND

Global climate is changing rapidly, and humans are very likely to have a significant role in affecting these changes (IPCC, 2007). Placing these anthropogenically-forced contemporary changes into a long-term context is crucial to our understanding of how the climate system works and for demonstrating the full range of its natural variability. As warming progresses, profound shifts in the cryosphere and biosphere are being observed, especially at higher latitudes (ACIA, 2004; D'Arrigo et al., 2007, Serreze et al., 2007). Of particular concern are the accelerated changes now taking place in the Arctic and Sub-arctic (Josberger et al., 2006; Rahmsdorf et al., 2007; Stroeve et al., 2008), and their link to an accelerated rise in eustatic sea level (Church and White, 2006; Meier et al 2007). It is with these observations in mind that we conducted research on the paleoclimate of Glacier Bay, a climatically-sensitive region of the North Pacific where we are presently generating and analyzing tree-ring records. For the North Pacific region, most observational climate records are less than 100 years long, spanning only the interval of possible anthropogenic influences. This paleoclimate data generated in this Keck project will help us to reconstruct critical parameters that are needed to understand climate dynamics of the North Pacific (e.g. Pacific Decadal Oscillation or PDO – Mantua et al. 1997).

OBJECTIVES

The Glacier Bay tree-ring record can be used to reconstruct key variables of North Pacific climate. In so doing, the student work presented here builds on our previous work over the past several decades, including most recently a study by Wilson et al. (2007) that identified regime shifts and climate changes for the GOA and their relation to North Pacific climate using a long tree-ring record dating back to the early eighth century. The proposed tree-ring record for Glacier Bay will allow us to extend such analyses much further back in time. As in Wilson et al. (2007), student work here has recognized past oscillatory modes for the North Pacific region and their relation to the variability of the PDO, Aleutian Low (Erlinger, this volume), Pacific North America pattern (PNA) and El Niño-Southern Oscillation (ENSO) (e.g. A. Plourde, this volume; D'Arrigo et al. 2005a and b), all prominent features of interannual to decadal-scale North Pacific climate variability.

We conducted our summer 2007 research entirely within Glacier Bay National Park and Preserve in southeast Alaska on the northeastern Gulf of Alaska (Fig. 1). The National Park encompasses well over 1.3 million ha, most of it designated wilderness. The Glacier Bay watershed, with ~26% ice cover, extends throughout most of the central area of the park. It is bounded to the west by the Fairweather Range and to the north and east by the Takhinsha Mountains (Figs. 1 and 2). With the exception of some lowlands at the southeastern and southwestern margins, all but the highest peaks within Glacier Bay were covered by ice during the Little Ice Age (LIA). Maximum extent was reached at about 1770, when the ice extended into Icy Strait beyond the current mouth of Glacier Bay (Motyka et al., 2003). By 1794, about 8 km of the bay was free of ice, as retreat had already begun when observed by Captain George Vancouver. This relatively recent loss of ice mass has had a significant effect on global sea level rise, contributing as much as 8 mm (Arendt et al., 2002, Larsen et al., 2005, 2007). Recession of tidewater glaciers from Glacier Bay is one of the best documented on the globe, with ice margins retreating distances over 120 km at some of the highest rates ever recorded (Powell, 1991). During this retreat, forests that were overridden by ice advance have been discovered. Radiocarbon dating and preliminary tree-ring dating of subfossil wood from these interstadial forests reveal that in addition to the LIA advance, ice apparently advanced into Glacier Bay several other times beginning as early as 10,000 years ago, thus indicating a highly active and variable region (Lawson et al, 2007; Mann and Streveler, in press; Monteith et al., 2007; Conner et al, in review).

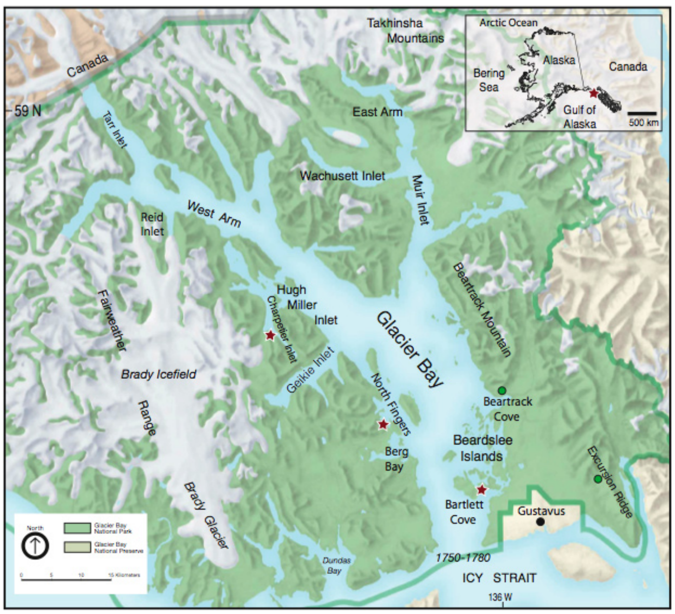

Figure 1. Locations within the Glacier Bay watershed of Glacier Bay National Park and Preserve (star in inset map). Note the advanced position of the ice margin near Icy Strait in the early to late 1700s. Beartrack Cove and Excursion Ridge (green dots) are the locations of the living tree-ring sites. We have also recovered subfossil wood (red stars) from multiple locations during the summer of 2007.

The primary aim of the project was to sample living trees and recover subfossil wood from Glacier Bay National Park and Preserve. This work contributes to the ongoing progress building a multi-millennial tree-ring chronology and assessing its climatic significance for the region. The ring-width chronology can be analyzed as a climate record and used in tree-ring dating of wood from the region. Our previous work in southern Alaska shows that ring-widths are primarily records of past temperature variability that can contribute to the reconstruction of climate. In addition, the crossdating and building of the long tree-ring series provides calendar dates for glacier advances in the park. Specific objectives were to:

Figure 2. View of Glacier Bay looking east toward the Takhinsha Mountains. The USGS research vessel Sigma T operated by the National Park Service is in the foreground.

1) Develop ring-width series from living trees spanning the past several hundred years,
2) Identify the climate signal in these series,
3) Use the tree-ring series in modeling climate in the North Pacific, and
4) Sample sections of subfossil wood that grew for various intervals through the past several millennia, incorporating resulting data into the long tree-ring series and build preliminary floating ring-width series.

Due to logistics and interests of the participants, we focused on the lower portion of the bay sampling subfossil wood from Charpentier Inlet south to Bartlett Cove, and the living tree-ring record on Excursion Ridge (Figs. 1 and 4). We collected four new living tree-ring sites (Table1, Fig. 1) and have processed two of these for ring-widths. Individual student projects are outlined in the subsequent sections (E. Erlanger, A. Plourde and A. Trutko, this volume)

Figure 3. Sampling mixed hemlock–spruce-cedar-pine forest along the western flank of Excursion Ridge, Glacier Bay.

Figure 4. Looking north from the Charpentier Fan. Researchers (right to left) A. Plourde, A. Trutko, E. Erlanger and D. Lawson return to the Sigma T.

PROGRESS IN TREE-RING ANALYSIS

Significant progress has been made in developing ring-width series and identifying the climate signal in these records from Glacier Bay. We have found a strong temperature signal in ring-width data from two tree-ring sites at Beartrack Cove and Excursion Ridge (Figs. 1, 2). These ring-width series have been combined with the growing network of tree-ring sites along coastal northern North America. The following three student contributions illustrate the range of applications that dendroclimatic modeling spans and also the challenges in working with tree-rings as unprecedented environmental change appears to be altering climate response of trees.

E. Erlanger successfully reconstructed Sitka air temperatures back several hundred years using the tree-ring data generated from this project along with six other ring-width series from the Gulf of Alaska. The Sitka meteorological record is the longest observational record in the North Pacific dating back to the 1830s with Russian Settlement of Alaska. Her well-verified tree-ring model clearly shows the decadal pace of the North Pacific and significantly extends the observational record back into the 16th century.

A. Plourde exploited a well-known teleconnection pattern – the Pacific North American (PNA) pattern - that links temperature variability in the North Pacific with moisture changes in the Great Lakes region of North America. Using a suite of tree-ring records from Alaska and the Pacific Northwest he was able reconstruct levels of Lakes Huron and Michigan. This work extends the existing monthly lake level records of the past 100 years for the Laurentian Great Lakes by several hundred years and allows a glimpse into the decadal to century-scale variability of this important water and ecological resource.

A. Trutko examined the phenomenon known as divergence at Excursion Ridge. Divergence is an underestimation of recent temperature trends in some tree-ring data (see D'Arrigo et al., 2007 for a review). We are now aware that growth divergence is a challenge in our chronology development from the region and about half of the core samples at the living tree-ring sites have experienced a relatively recent (past several decades), unexplained decrease in growth. This realization has bearing on Erlanger's work that used the Excursion ring-width record in her modeling efforts.

In addition to his individual student project, Plourde was successful in crossdating logs sampled during 2005 and our work in 2007, from the uplifting intertidal zone near the southern end of the fjord system. These logs date to the recent LIA advance.

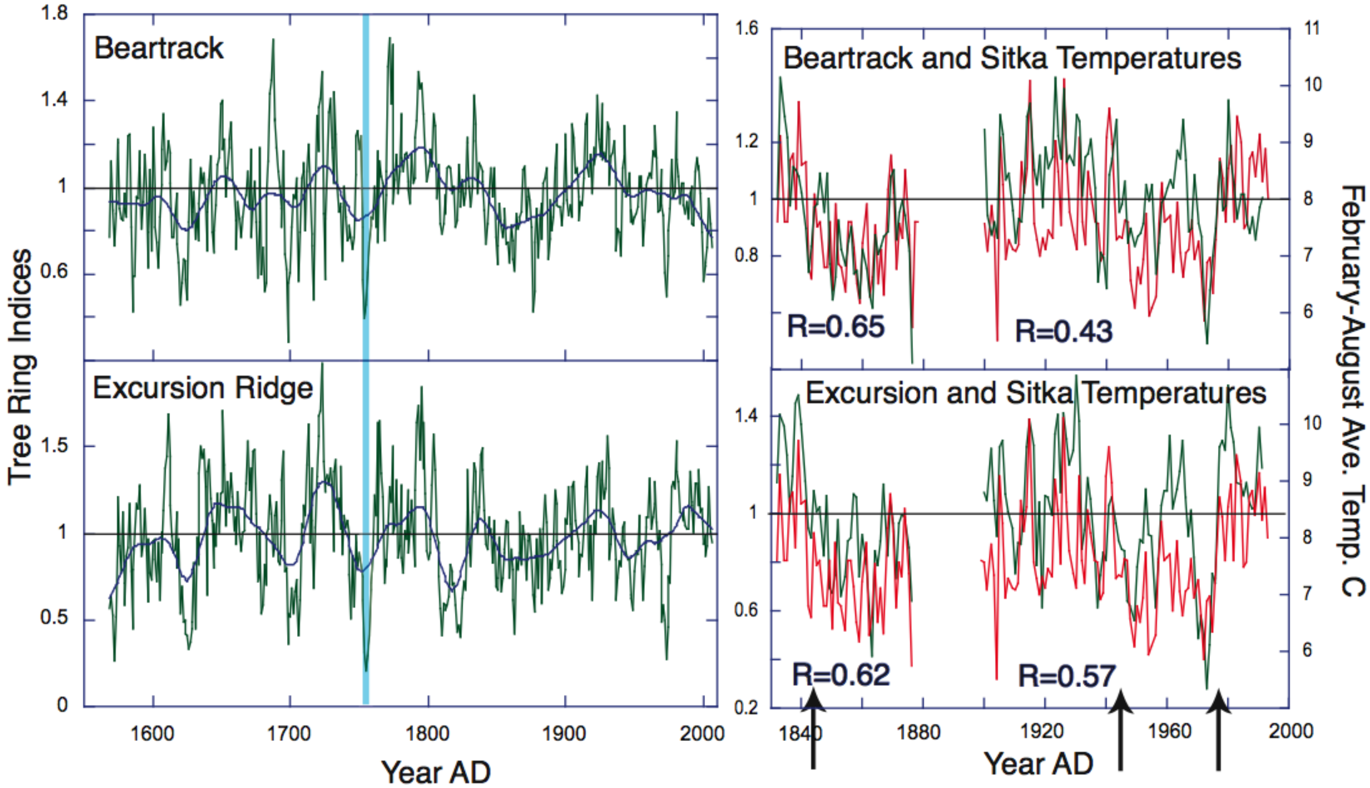

Figure 5. Two living tree ring-width series from Glacier Bay that show a strong temperature signal. Both series correlate strongly with February through August average temperatures from Sitka, AK, in the 1800s and 1900s (right panels). The gap is due to a discontinuity in the station record during the transfer of Alaska from Russia to the United States – E. Erlanger's work (this volume) estimated missing values using her modelling. Note that both tree-ring series show abrupt changes (arrows) in temperature during the 1970s and early 1940s, known regime shifts (Ebbesmeyer et al., 1990; Mantua et al., 1997) and another possible shift about 1840. Further analyses of this record and its comparison to other records from GOA are currently being done for an undergraduate thesis (Erlanger, in progress). Note that both Beartrack and Excursion Ridge series tail off in their growth toward the end of the record (left panels); this appears due to a loss of climatic sensitivity (divergence). Blue shading in the left panels shows a cold interval that may be related to Tlingit legends that describe two years of continuous winter conditions (Connor et al., in review).

Calendar dates on the outer rings of the logs show that the trees were killed near the mouth of Bartlett Cove between 1704 and 1724, and 5.25 km to the south by 1735 (Fig. 1). The significance of these dates with regard to glacier history is still under discussion, but appears to record an incredibly fast rate of ice advance. Connor et al. (in review) suggest, based on radiocarbon dates, that the LIA advance to Bartlett Cove occurred about AD 1680, while our tree-ring dates suggest advance through that region between 1704-1735. Additionally, native Tlingit legends report two years of continuous winter conditions about the time of the Tlingit-evicting LIA ice advance (summarized in Connor et al., in review). Interestingly, our tree-ring records show extreme cold between 1752 and 1754, possibly reflecting this event (Fig. 2 and Erlanger, this volume).

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